

## INFLUENȚA DURATEI DE PĂSTRARE ASUPRA CALITĂȚII MERELOR INFLUENCE OF STORAGE DURATION ON APPLE FRUIT QUALITY

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### Abstract

During cold storage 2015 - 2016, changes in fruit quality parameters at thirteen apple varieties ('Generos', 'Rustic', 'Ciprian', 'Topaz', 'Luna', 'Opal', 'Sirius', 'Rajka', 'Goldrush', 'Crimson Crisp', 'Dalinette@Choupette', 'Dalinco', 'Ariwa') were studied in order to determine the maximum storability time at +4°C and 95% RH. The fruits were tested in the Genetic and Breeding Department of the Institute for Fruit Growing Pitesti, Romania from November 10, 2015 till January 19, 2016, at 15 days storage intervals. During first two weeks of storage, there was no change in colour and then it was changed gradually. At end of cold storage the flesh firmness declined at 6.18 kg cm<sup>-2</sup> for 'Ciprian' cv. and 6.90 kg cm<sup>-2</sup> for 'Rajka' cv. Increasing storage duration increased the total soluble solids content till 14,158% for 'Golden Delicious' cv. (Ct 3) and 14,098% for 'Ariwa' cv.

**Cuvinte cheie:** măr, perioada de păstrare, fermitate, parametrii de culoare, conținut în substanță uscată solubilă

**Key words:** apple, storage duration, firmness, color parameters, total soluble solids content

### 1. Introduction

Apple (*Malus domestica* Borkh.), one of the most important tree fruit of the world, belongs to the family Rosaceae and sub-family Pomoideae. In apple production, only a low percentage of fruits could be sold immediately after the harvest time, while the largest part is stored for an extended period of time to keep them available for a market (Kovač et al., 2010).

In Romania, generally, the apple harvest time is during end of August till end of September and much of the fruit is supplied to the markets for fresh consumption, but the prices are generally low during the harvest season. Thus, storage is required to catch good market price and ensure its supply during the off-season. The apple is climacteric fruit and hence its quality declines after harvest due to respiration and ethylene production (Kader, 2002). In relatively cooler climates, simple warehouses can be used for storing apples, but cold storage is required for long term storage and quality retention (Mitropoulos and Lambronis, 2000).

Many factors affect fruit quality, including genetics, soil properties and weather conditions. During the storage time, quality of apples is changing. Physical and chemical analysis can establish changes in fruit quality depending on storage time. Besides quantitative losses, the loss of chemical quality and texture is also a serious problem in stored apples (Kov and Felf, 2003). In general, apple fruit harvested at immature stage have poor color and flavour and more susceptible to physiological disorders such as bitter pit and superficial scale (Kvikliene et al., 2008). By contrast fruits harvested over mature tend to be soft and easily damaged during postharvest operations (Ganai et al., 2015). Such fruits are more susceptible to diseases and physiological disorders as well as quality deterioration during or after storage (Ingle et al., 2000).

The objective of this study was to evaluate different apple cultivars in terms of how the quality attributes of their fruit crop are affected by storage duration in cold storage.

### 2. Material and methods

The study was carried out at Research Institute for Fruit Growing Pitesti, Genetic and Breeding Department, during harvest season 2015 - 2016. Change in fruit quality parameters at thirteen different origin apple cultivars: 'Generos', 'Rustic', 'Ciprian' from Romania, 'Topaz', 'Luna', 'Opal', 'Sirius', 'Rajka' from Czech Republic, 'Goldrush' and 'Crimson Crisp' from USA, 'Dalinette@Choupette', 'Dalinco' from France, and 'Ariwa' from Switzerland were evaluated during 4 months of cold storage. As control, the commercial variety 'Florina' (Ct1), 'Idared' (Ct2) and 'Golden Delicious' (Ct3) were used. The trees grafted on M9, were planted in spring 2009, at 4 meters between rows and 1 m between trees. Soil between rows was grass covered and inter row spaces were treated with herbicides.

Healthy, uniformly-sized and without visible external damage fruits were taken at the optimal harvest time (20 fruits per sample) and stored at +4°C and 95% relative humidity. Then, starting with November 10, 2015 till January 19, 2016, at 15 days storage intervals, physical and chemical analysis of fruits were taken.

Flesh firmness was measured on two opposite sides of each fruit with a penetrometer HPE II Fff Qualitest (Qualitest Inc., Canada), with a plunger of diameter 1.0 cm<sup>2</sup>; results were expressed in kgcm<sup>-2</sup>.

Soluble solids content (SSC) were determined by using digital refractometer PR 32 (Atago, Japan) at room temperature. The extracted juice was shaken well by a shaker. The representative sample was placed (drop) on a absolutely dry refractometer prism and the reading was taken directly (°Brix).

Fruit skin color was determined with a chromometer (Model CR-400, Konica Minolta, Japan), equipped with an 6-mm measuring head. The meter was calibrated using the manufacturer's standard white plate. Color changes were quantified in the L\*, a\*, b\* color space. L\* refers to lightness of the color of the skin apples and ranges from black = 0 to white = 100. A negative value of a\* indicates a green color where the positive value indicates red-purple color. A positive value of b\* indicates a yellow color and the negative value a blue color. According to the CIE Lab system, the hue angle ( $h^0 = \arctan(b^*/a^*)$ ) and chroma index ( $C = (a^{*2} + b^{*2})^{1/2}$ ) were calculated.

The differences between the evaluated cultivars were assessed using analysis of variance, general linear model procedure (one way ANOVA and LSD test at P≤5; 1; 0.1 level). The cultivars were compared with the control cultivars.

### 3. Results and discussions

**Flesh firmness.** The maximum average of flesh firmness (8.45 kg cm<sup>-2</sup>), at end of the evaluate period, was registered at 'Dalinette@Choupette' cv., follow by 'Ariwa' with 8.42 kg cm<sup>-2</sup> and 'Goldrush' cv. with 8.09 kg cm<sup>-2</sup>. Fruit firmness is an important criteria for fruit quality of apples (De-Ell *et al.*, 2001, Weibel *et al.*, 2004) and the loss of fruit firmness is a serious problems in postharvest handling old apple fruits (Kov and Felf, 2003), because it resulted in soft and mealy fruit with poor consumers acceptance. A rapid decrease at flesh firmness was recorded at 'Ciprian' cv. (6.18 kg cm<sup>-2</sup>) and 'Rajka' cv. (6.90 kg cm<sup>-2</sup>), and also, 'Dalinco' cv. (7.27 kg cm<sup>-2</sup>). Rapid post harvest softening of apples was caused by water loss due to transpiration and cell wall breakdown due to enzymatic activities (Kweon *et al.*, 1998).

**Soluble solids content (SSC).** The total soluble solids content of apple fruit is a good indicator of sugar content and presumably of sweetness; it is significantly affected by storage duration. Usually later picked apples show higher SSC values not only at harvest time, but at the end of storage too (Yong Soo *et al.*, 1998). In our study, the minimum average of SSC was recorded at 'Idared' cv. (Ct2) with 11.65 °Brix and at 'Rustic' cv. with 11.87 °Brix. Total soluble solids, generally, increased during storage (Mahajan, 1994). For all studied varieties were observed an increase of soluble solids content in the first 2-3 assessments, until December, followed by a slow decrease of this index of quality. As exception, 'Goldrush' cv. has a progressive increase in soluble solids content, from 11.15°Brix at the first assessment in November 10, 2015 to 14.45°Brix last assessment in January 19, 2016. So, it recommends that stored fruit consumption period of the variety 'Goldrush', to start at the earliest in January, after minimum 3 months of storage. The highest average of SSC was registered at 'Golden Delicious' cv. (Ct3) with 14.158°Brix, followed by 'Ariwa' cv. with 14.098 °Brix.

**Fruit color.** Color changes are the most obvious signal for fruit ripening. During ripening, apple fruit generally shows a rapid loss of green color which results from the degradation of chlorophyll structures (Tromp, 2005). The yellow to red color of apples, which is due to anthocyanins and carotenoids in the peel, becomes visible with chlorophyll decline (Kingston, 1992; Tromp, 2005). For apple varieties with red skin color ('Crimson Crisp', 'Dalinette@ Choupette', 'Ciprian'), and also, bicolor ('Dalinco', 'Rustic', 'Rajka', 'Ariwa'), the average value calculated for hue angle (h) and chroma index (C\*) were positive, with small difference between an evaluation period to another (figure 1, A to I). For 'Generos' cv., the skin apples color changed in the first decade of December, and the lightness coordinate decreased from positive to negative values (figure 1, J). For apple varieties with green skin color ('Goldrush', 'Luna', 'Opal', 'Sirius'), the hue angle recorded negative value, decreasing throughout the storage period; this indicated the predominance of yellow color of fruits skin (Fig. 1, K to N).

### 4. Conclusions

The major aim of the present one year model experiment was to evaluate a larger set of apple cultivars, by regularly monitoring, what are the changes of the various fruit quality parameters in order to establish the time of optimal consumption. 'Ciprian' and 'Rajka' cvs. recorded, at the end of the evaluation period, firmness values below 7 kgcm<sup>-2</sup>. It is considered that apples were down in terms of quality, loss of firmness being associated with overcoming of consumption. Also, low level of firmness was recorded at

'Dalinco' cv. So, for all these varieties make the recommendation that, the optimum period of consumption could be, at most, until mid of December.

Regarding soluble solids content, at 'Goldrush' cv. was registered a progressive increase, so, we recommend that the consumption starts after minimum 3 months of cold storage.

Fruit color intensity depends on cultivar properties and the lightness coordinates changed for all apple cultivars studied during storage.

## 5. Acknowledgements

This paper was published under the project ADER 3.1.2/2015.

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## Tables and figures

Table 1. List and background information of apple cultivars studied

No.	Cultivar	Institution	Reported parentage
1	Generos	Research Station for Fruit Growing Voinești, Romania	(Parmain d'or x <i>Malus kaido</i> ) x (Jonathan x Frumos de Voinești)
2	Ciprian		Prima x Starkrimson
3	Rustic	Research Institute for Fruit Growing Pitesti, Romania	Florina x Pionier
4	Topaz	Institute of Experimental Botany Strizovice, Czech Republic	Rubin x Vanda
5	Luna		Topaz x Golden Delicious
6	Opal		Golden Delicious x Topaz
7	Sirius		Golden Delicious x Topaz
8	Rajka		Champion x Katka
9	Goldrush	Illinois, SUA	Golden Delicious x Coop 17
10	Crimson Crisp	Rutgers, SUA	PCFW 2-134 x NJ669-205
11	DalINETTE® Choupette	INRA Angers, France	Sel. X 4598 x Sel. X 3174
12	Dalinco	INRA + Ligonnere, France	Elstar x Sel. X3191
13	Ariwa	FAW Wadenswil, Switzerland	Golden Delicious x Sel. A849-5
14	Florina (Ct 1)	INRA, France	Complex hybrid ( <i>M. floribunda</i> 821, Rome Beauty, Golden Delicious, Jonathan)
15	Idared (Ct 2)	Idaho, SUA	Jonathan x Wagener premiat
16	Golden Delicious (Ct 3)	Westvirginia, SUA	Grimes Golden x Golden Reinette

Table 2. Change of flesh fruit during storage

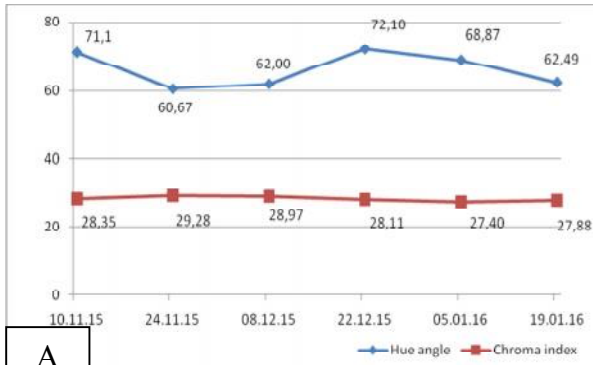
No.	Cultivar	Firmness (kg cm <sup>-2</sup> )						Average	± Ct1	± Ct2	± Ct3
		11.10	24.11	12.08	12.22	01.05	01.19				
1	Generos	7.59	7.41	7.51	7.19	7.24	7.20	7.356			
2	Ciprian	7.64	7.78	7.59	7.35	6.92	6.18	7.245			
3	Rustic	7.86	7.85	7.72	7.47	7.43	7.54	7.645			
4	Topaz	7.86	7.41	7.70	7.43	7.34	7.17	7.485			
5	Luna	8.15	8.07	7.97	7.69	7.63	7.49	7.833			
6	Opal	7.88	7.77	7.76	7.53	7.51	7.42	7.645			
7	Sirius	7.99	7.77	7.53	7.46	7.36	7.21	7.553			
8	Rajka	7.61	7.54	7.40	7.29	6.90	6.88	7.270			
9	Goldrush	8.39	8.20	8.12	8.06	7.90	7.86	8.088	xxx	xxx	xxx
10	Crimson Crisp	8.25	8.23	8.09	7.97	7.94	7.60	8.013	xx	xx	xxx
11	DalINETTE® Choupette	8.62	8.56	8.46	8.41	8.40	8.28	8.455	xxx	xxx	xxx
12	Dalinco	7.57	7.46	7.31	7.17	7.12	7.03	7.276			
13	Ariwa	8.77	8.42	8.39	8.35	8.34	8.27	8.423	xxx	xxx	xxx
14	Florina (Ct 1)	7.97	7.76	7.65	7.55	7.32	6.97	7.536			
15	Idared (Ct 2)	7.74	7.68	7.61	7.47	7.43	7.35	7.546			
16	Golden Delicious (Ct 3)	7.69	7.48	7.47	7.44	7.36	7.23	7.445			

DL5% = 0.306, DL1% = 0.405, DL0.1% = 0.523

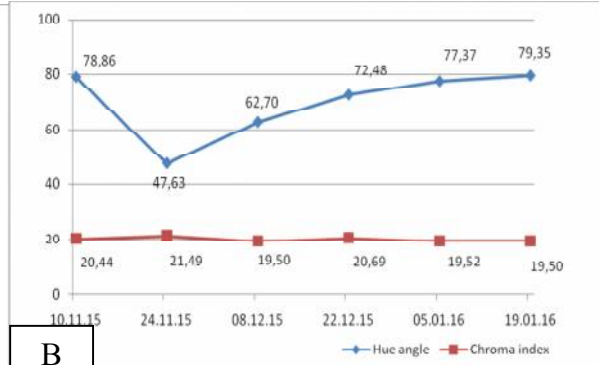
**Table 3. Change of soluble solids content during storage**

No.	Cultivar	Soluble solids content ( <sup>o</sup> Brix)						Average	± Ct1	± Ct2	± Ct3
		11.10	24.11	12.08	12.22	01.05	01.19				
1	Generos	12.45	13.55	13.65	12.30	12.00	11.85	12.633			0
2	Ciprian	12.70	13.15	12.80	12.95	12.20	11.10	12.483	0		00
3	Rustic	12.75	12.70	12.20	11.70	11.10	10.80	11.875	00		000
4	Topaz	14.00	13.80	14.00	13.65	11.75	10.20	12.900			0
5	Luna	11.75	13.80	14.10	13.72	12.25	9.45	12.511	0		00
6	Opal	11.55	12.85	12.70	12.10	12.10	11.05	12.058	00		00
7	Sirius	11.65	14.25	13.95	12.95	12.75	11.80	12.891			0
8	Rajka	13.40	14.15	14.00	13.55	12.70	11.30	13.183		x	
9	Goldrush	11.15	11.80	12.10	12.20	12.45	14.00	12.283	00		00
10	Crimson Crisp	13.60	13.70	13.70	13.45	13.30	12.25	13.333		x	
11	Dalinette® Choupette	12.30	13.40	14.55	13.35	12.30	11.20	12.850			0
12	Dalinco	12.75	14.45	13.50	13.20	12.50	10.55	12.825			0
13	Ariwa	11.95	14.70	14.80	14.95	14.25	13.94	14.098		xxx	
14	Florina (Ct 1)	14.20	15.65	14.25	13.70	13.00	12.50	13.883			
15	Idared (Ct 2)	13.15	13.10	11.75	10.95	10.70	10.25	11.650			
16	Golden Delicious (Ct 3)	16.00	16.35	14.85	13.25	12.85	12.45	14.291			

*DL5% = 1.329, DL1% = 1.757, DL0.1% = 2.269*



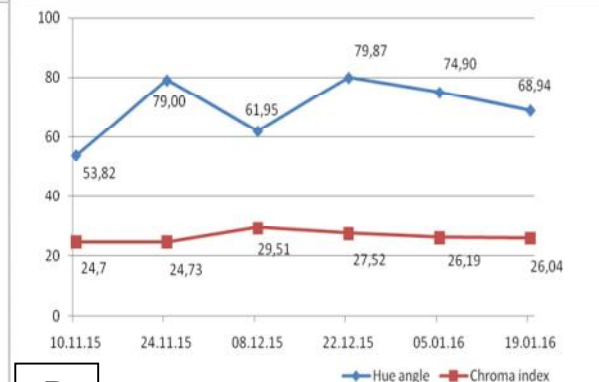
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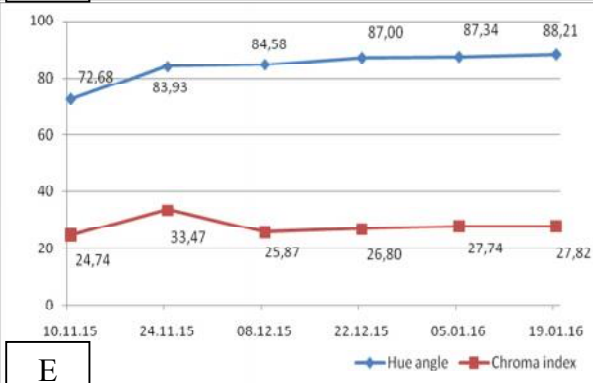
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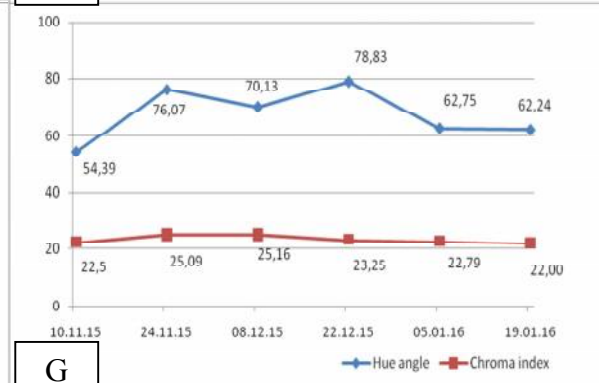
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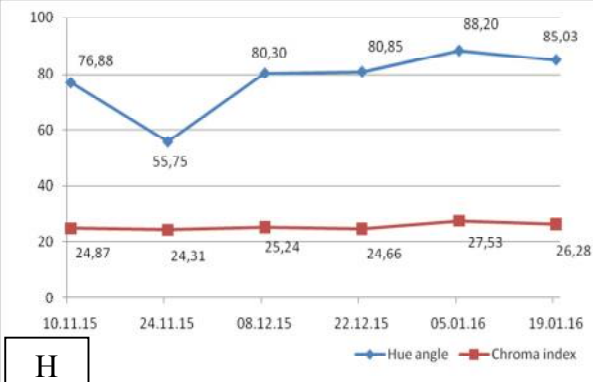
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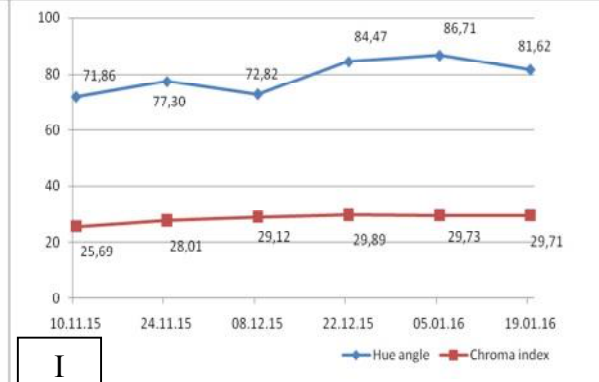
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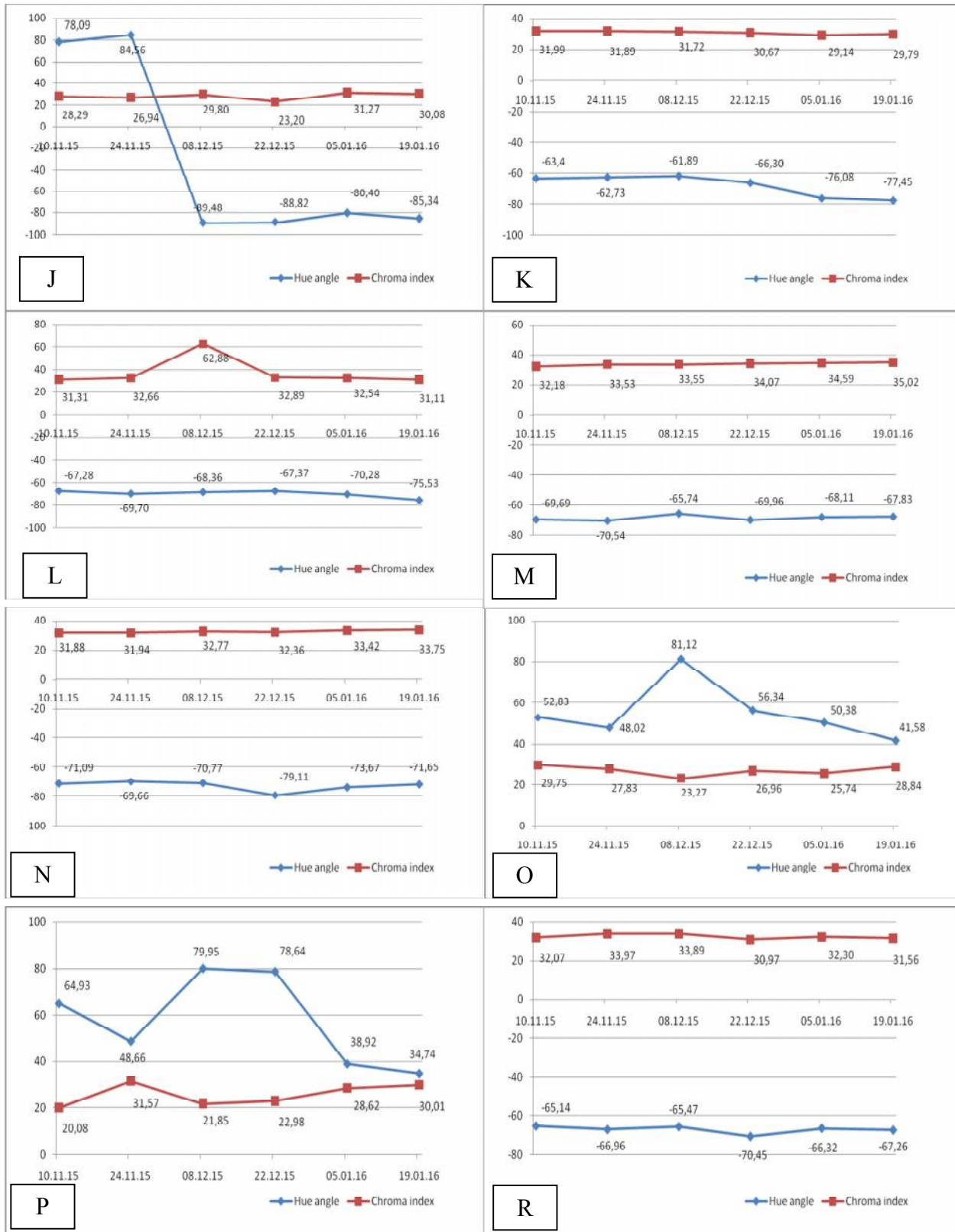


Fig. 1. Change of skin color of apples during storage

A. `Crimson Crisp`, B. `Dalinette® Choupette`, C. `Ciprian`, D. `Topaz` cvs. (red skin color)  
 E. `Dalinco`, G. `Rustic`, H. `Rajka`, I. `Ariwa`, J. `Generos` cvs. (bicolor)  
 K. `Goldrush`, L. `Luna`, M. `Opal`, N. `Sirius` (green)  
 O. `Florina` (Control 1), P. `Idared` (Control 2), R. `Golden Delicious` (Control 3)

Hue angle: DL5% = 27.166; DL1% = 36.040; DL0.1% = 46.552  
 Chroma index: DL5% = 4.347; DL1% = 5.767; DL0.1% = 7.448